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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20545

(NASA-Case-LAR-10318-1) METHOD OF
FABRICATING AN ARTICLE WITH CAVITIES
Patent (NASA) 5 p

N74-18089

CSCL 14B

REPLY TO
ATTN OF:

GP

Unclas
00/14 30858

TO: KSI/Scientific & Technical Information Division
Attn: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General
Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No.

: 3,793,109

Government or
Corporate Employee

: U.S. Government

Supplementary Corporate
Source (if applicable)

: _____

NASA Patent Case No.

: LAR-10,318-1

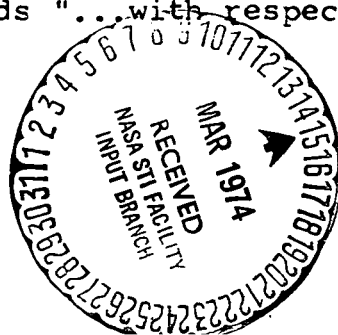
NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:

YES ☐

NO ☒

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words "...with respect to an invention of ..."

Bonnie L. Woerner
Enclosure



[54] **METHOD OF FABRICATING AN ARTICLE WITH CAVITIES**

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[73] Assignee: **The United States of America as represented by the Administrator of the National Aeronautics and Space Administration**, Washington, D.C.

[22] Filed: **Feb. 8, 1972**

[21] Appl. No.: **224,489**

[52] U.S. Cl. **156/245, 156/285, 156/309, 156/247**

[51] Int. Cl. **C09j 5/02, C09j 7/00**

[58] Field of Search **156/64, 83, 212, 215, 247, 156/285, 287, 309, 245; 73/190 H, 190 R; 29/612**

[56] **References Cited**

UNITED STATES PATENTS

3,382,714	5/1968	Miller et al.	73/190 H
3,676,238	7/1972	Furlong et al.	156/285 X

Primary Examiner—**Alfred L. Leavitt**

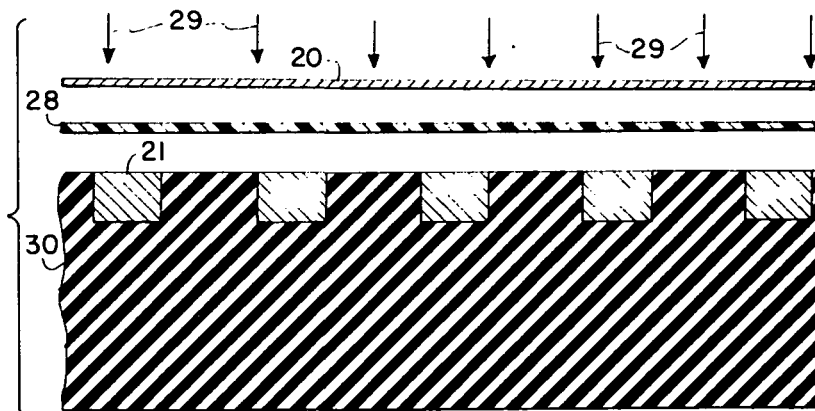
Assistant Examiner—**Basil J. Lewis**

Attorney, Agent, or Firm—**Howard J. Osborn; Nelson, Wallace J.; John R. Manning**

[57] **ABSTRACT**

An article having a cavity with a thin bottom wall is provided by assembling a thin sheet, for example, a metal sheet, adjacent the surface of a member having one or more apertures extending to that surface. A bonding adhesive is interposed between the thin sheet and the subadjacent member and the thin sheet is subjected to a high fluid pressure to subject the assembly to a high differential pressure to laminate the thin sheet to the member. In order to prevent the differential pressure from being exerted against the thin sheet adjacent the apertures in the subadjacent member, the aperture is filled with a plug of solid material having a linear coefficient of thermal expansion higher than that of the member. When the assembly is subjected to pressure, the material is heated to a temperature such that its expansion exerts a pressure against the thin sheet thus reducing the differential pressure across the thin sheet adjacent the plug. It is thus possible to readily produce members having hundreds of cavities having thin, flat, bottom walls. Stainless steel members are readily produced, for example, with seventy four such cavities, each with a diameter of 0.750 inches and having a flat bottom wall having a thickness of 0.006 inches.

15 Claims, 4 Drawing Figures



3,793,109

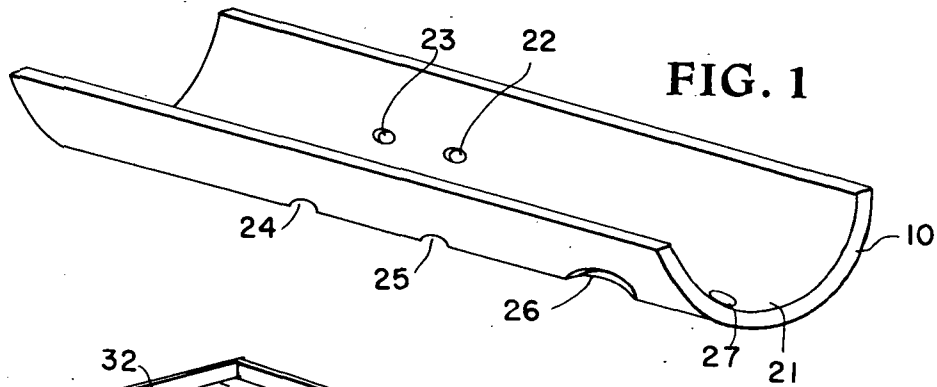


FIG. 1

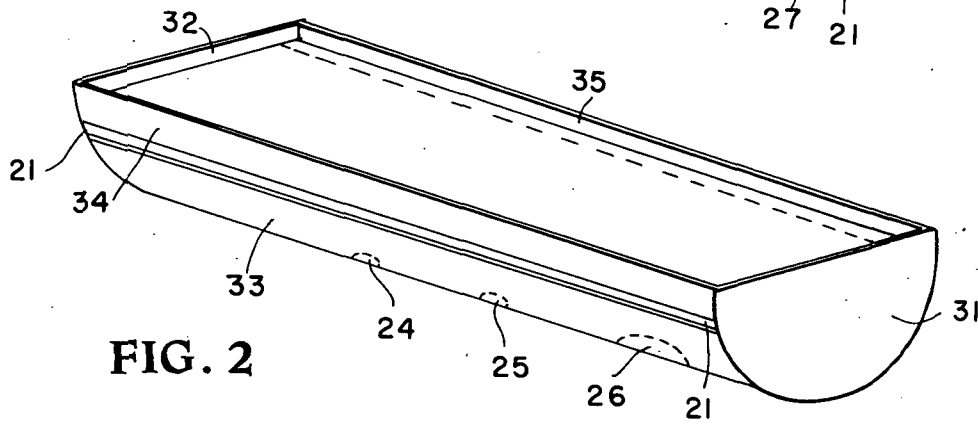


FIG. 2

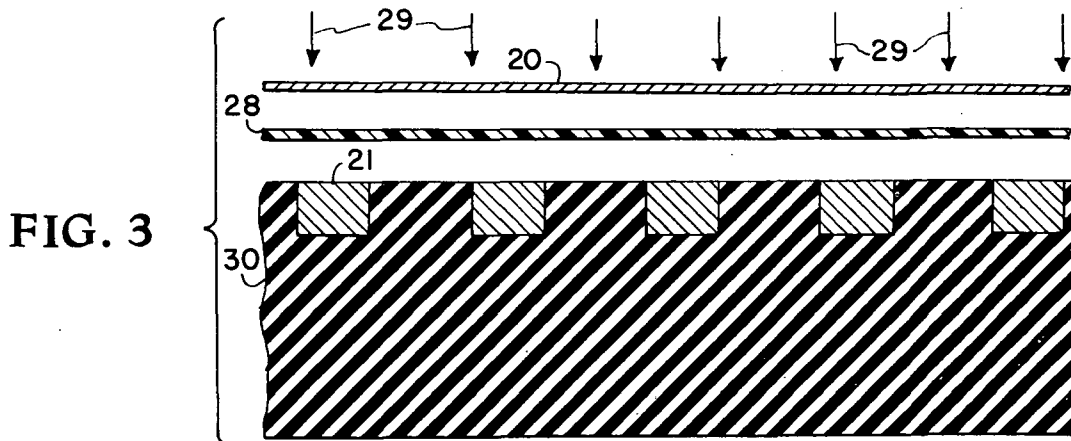


FIG. 3

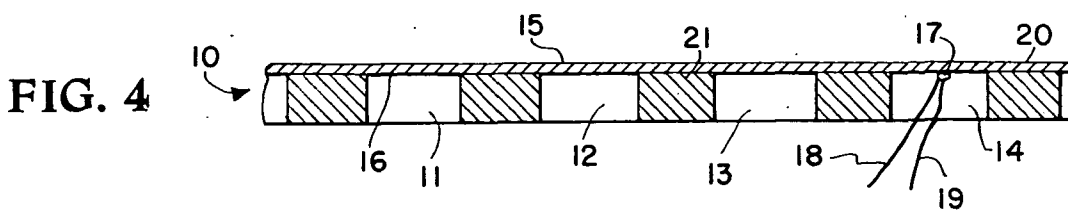


FIG. 4

METHOD OF FABRICATING AN ARTICLE WITH CAVITIES

ORIGIN OF THE INVENTION

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

The present invention relates to a method of forming members with cavities therein having thin, flat, bottom walls. A need frequently arises for providing cavities with a very thin and flat bottom wall the thickness of which is uniform. For example, a cavity having a diameter of 0.750 inches in diameter having a bottom wall 0.006 inches thick is useful in detecting temperature characteristics of the bottom wall. A thermocouple is attached to the bottom wall and temperature is detected in the normal way. The cavity thus forms a calorimeter with a uniform surface thickness and finish. Successful application of the concept requires ability to provide a dimple-free and wrinkle-free bottom wall, normally of metal, thin enough to provide desired sensitivity to temperature change to produce an electrical signal that may be recorded with accuracy simultaneously over a given surface area while operating under various temperature conditions.

Machine tooling an article of this type, particularly one with several cavities, with the bottom cavity wall being an integral part of the model is feasible, but not practical. This would require the use of an Elox machine to electrode-form the cavities. A minimum of two electrodes, one for roughing out and the second for the final finishing, would be required for each cavity.

The machining operation would require approximately 4 to 6 man-hours per cavity, with the finished model depending on the ability of the individual machinist to complete the required number of intricate machining operations, leaving the identical thickness of bottom wall in each of the cavities. Due to the number and complexity of the required machining operations, the possibility of human error, machine malfunction, or electrode burn through at any one of the cavities, is always present.

Machining an article of this type and chemical milling the cavities with each cavity being an identical 0.750 diameter, straight edged, radiused faced opening having a finished 6 mil skin thickness is not feasible.

Because of the dubious propagation controlling ability of the chemical milling process in relation to gauging the depth of the milling operation and the crystallization of the metal being etched, it is highly improbable to duplicate any set number of operations. Due to the number of variables and chances of rejection, chemical milling an article of this configuration, particularly one with a curved surface, would not be feasible.

In view of the foregoing, it is readily seen that conventional fabricating techniques have several disadvantages including high cost, a high possibility of rejection when a large number of cavities is provided, the quality of the finished article is dependent totally on the machine operator's skill, a possibility of changing the materials properties at the cavity bottom wall due to the type of machining employed, and difficulty of duplica-

tion of properties such as sensitivity, specific heat, and thickness at each cavity bottom wall.

It is therefore an object of the present invention to provide a novel method for fabricating members having one or more cavities having thin bottom walls. It is still a further object to provide such a method which overcomes the disadvantages of conventional methods of fabricating such members.

The foregoing and other objects which will be apparent to those having ordinary skill in the art are achieved by providing, in a method of bonding a thin sheet to a substrate including an aperture therein wherein the sheet is assembled adjacent the substrate and the assembly is subjected to a high differential pressure to bond the thin sheet to the substrate, the improvement wherein the aperture is filled with a plug of a solid, heat expandable material having a linear coefficient of thermal expansion at least as high as that of the substrate and wherein the plug of material is heated while the assembly is subjected to the differential fluid pressure to a temperature such that the pressure against the thin sheet induced by the thermal expansion of the plug of material is sufficient to substantially reduce the high differential pressure across the thin sheet adjacent said plug.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

There follows a detailed description of a preferred embodiment of the invention, together with accompanying drawings. However, it is to be understood that the detailed description and accompanying drawings are provided solely for the purpose of illustrating a preferred embodiment and that the invention is capable of numerous modifications and variations apparent to those skilled in the art without departing from the spirit and scope of the invention.

FIG. 1 is a perspective view of a stainless steel member including a plurality of apertures used to fabricate an article according to the present invention;

FIG. 2 is a perspective view of the member of FIG. 1 with elastomeric material filling the apertures in the member;

FIG. 3 is a sectional diagrammatic exploded view showing a portion of a sheet being bonded to the member of FIG. 2;

FIG. 4 is a sectional view of an article according to the invention produced after bonding as shown in FIG. 3 and including a plurality of cavities having thin bottom walls.

FIGS. 1-4 illustrate application of the invention to the fabrication of a hollow conically shaped stainless steel article having seventy four cavities of various diameters. The article is made up of two halves, a portion of one half being diagrammatically shown in FIGS. 1 and 2. Member 10 is fabricated by conventional technique from type 347 stainless steel 0.20 inches thick and is provided with a plurality of cavities 11-14 having a diameter of 0.750 inches and having a flat bottom wall 15 0.006 inches in thickness. Member 10 may be in any configuration and in this case is one half of a cone, a portion only of the half being shown in FIGS. 1 and 2. The article is used to analyze the boundary layer adjacent the outer surface of the conical article. For example, the article may be used to analyze surface temperature when the conical article is subjected to motion relative to fluid. In one specific use, the conical

article is used to analyze surface temperature when the conical article is moved through a fluid. In this case, each cavity is used as a calorimeter. The inner surface 16 of the bottom wall 15 of each cavity is provided with a thermocouple junction one of which is shown and designated by reference numeral 17 and having conventional electrical leads 18, 19. Thermocouple junction 17 is attached to surface 16 by any conventional technique such as welding. It is essential that thin wall portions 15 are dimple-free and wrinkle-free and yet thin enough to give desired sensitivity to produce an electrical signal which may be recorded with accuracy. It will be apparent that there are many other instances where it will be desired to produce a member having one or more cavities having very thin, flat, bottom walls. A member of this type is fabricated according to the present invention by bonding a thin sheet member 20 (FIG. 3) to the outer surface of a perforated member 21. The apertures 22-27 in perforated member 21 (FIG. 1) form the side walls of cavities 11-14 and the portions of sheet member 20 adjacent the apertures in member 21 form the flat bottom wall portions of the cavities.

Sheet member 20 is bonded to member 21 by means of a conventional laminating adhesive 28 disposed between sheet member 20 and member 21 as shown in FIG. 3. A uniform fluid bonding pressure is applied externally of sheet 20 as indicated by arrows 29 to bond sheet 20 to member 21. It will be readily understood, however, that bonding in this manner would subject the bottom wall portions 15 to a differential pressure which would cause distortion and even rupture of the thin bottom wall portions 15 under pressures normally employed during lamination. This is overcome according to the present invention by filling the apertures in member 21 with a plug 30 of a heat expandable solid material having a linear coefficient of thermal expansion at least as high as that of member 21 prior to exerting bonding pressure. The material is then heated simultaneously with the application of bonding pressure. The heat applied is sufficient to expand the plug of material sufficiently to substantially reduce the differential pressure across portions 15 of thin sheet member 20.

Preferably, plug 30 is formed in situ in the apertures in member 21 and a suitable technique is illustrated in FIGS. 1 and 2. A stainless steel (type 347) sheet 0.020 inches in thickness is formed as shown in FIG. 1 to constitute a portion of a hollow conical article being fabricated. Several apertures 22-27 are provided including several having a diameter of 0.750 inches. The open ends of the half-cylinder are sealed with aluminum foil sheets 31 and 32 taped to member 21. The outer surface of member 21 is covered with a suitable material 33, for example a mylar film, such that all of the apertures in member 21 are covered. Additional pieces of aluminum foil 34, 35 are taped to the edges of member 21 forming a mold cavity adjacent the concave inner surface of member 21. The mold cavity is then filled with a previously prepared liquid mixture commercially available Silicone Rubber composition (RTV 60 Silicone Rubber and Thermolite 12 Catalyst, General Electric, the catalyst being used in an amount of one percent by weight of the silicone rubber). The liquid composition sets to a solid elastomeric synthetic rubber is about 4 hours of 75° F.

After the rubber is set and the Mylar film and aluminum foil removed, a sheet of stainless steel 20 (Type

301, having a thickness of 0.006 inches) shaped to conform to the outer convex surface of member 21 is bonded to member 21 using a conventional heat sensitive adhesive film 28 (FM 1044, 0.001 inches in thickness, Americal Cyanamide). After cleaning and priming the metal surfaces, adhesive layer 28 is interposed between sheet 20 and member 21. The assembly is then placed below an impervious rubber sheet secured to a rigid frame in an autoclave. Vacuum is applied below the frame to draw the rubber sheet tightly against the outer surface of sheet 20 of the assembly. Steam is then introduced under pressure into the autoclave to exert a bonding pressure against the rubber sheet and the subadjacent sheet 20. A differential pressure thus urges sheet 20 against silicone rubber element 30. If the plugs of silicone rubber were not present in cavities 11-14, portions 15 of steel sheet 20 would be severely distorted or ruptured under conventional bonding temperature. However, plugs 30 in cavities 11-14 will expand due to the heat induced by the steam which heat is also utilized to cure the adhesive layer 28. The coefficient of thermal expansion of the silicone rubber is such that at the temperature used to cure the adhesive, the pressure exerted by plugs 30 outwardly against portions 15 of sheet 20 is substantially the same as the differential bonding pressure exerted against sheet 20 by the steam. Thus, the net differential pressure across portions 15 of sheet member 20 will be at or near zero.

It will be readily apparent that the thermal coefficient of expansion of the material making up plugs 30 should be at least as high as that of member 21. Where the solid plug material 30 is more resilient than member 21, its coefficient of thermal expansion should be higher than that of member 21. In any event, it is a simple matter to select a 30 plug material which will exert the required pressure at a given temperature.

The material of members 20 and 21 can vary widely, but are each preferably metal. The adhesive may be any conventional laminating adhesive and may be curable at ambient temperature or with heat. The plug material can also vary widely and is selected by its physical characteristics of temperature expansion and not by its chemical nature. However, it is preferred that the plug material be formed in situ in the apertures in member 21. Accordingly, liquid compositions settable to solids having the proper thermal expansion coefficient are preferred. The solid plug material is preferably resilient and resins and rubbers are preferred. These compositions can be filled with other materials, such as metals, to modify the coefficient of thermal expansion characteristics as desired.

Where the configuration of the member is complex, as in the illustrated embodiment, a resilient material, formable in situ, is preferred for the plug material. Suitable resilient materials have a linear coefficient of thermal expansion great enough to equalize the pressure differential at the apertures when the assembly is subjected to elevated temperatures and pressure. The material preferably is sufficiently resilient to allow the removal of the mandrel from the sub-structure, without disturbing the bonded assembly at the aperture areas.

Where a rigid material, such as rigid resin, is used to form the mandrel, the mandrel would become mechanically locked in the apertures, requiring breakaway force to remove which would subject the thin skin to possible damage at the aperture areas.

The mandrel material is cured prior to the assembly of the skin to the substrate and, in the illustrated embodiment, is capable of withstanding the relatively high curing temperature (330° F) of the adhesive film used to bond the skin to the substructure.

The selection of the mandrel material is governed to some extent by the type of adhesive system used to bond the skin to the sub-structure. The selection of the adhesive system is in turn governed to some extent by the end use temperature of the completed model. In the illustrated embodiment, the required use temperature is minus 400° to plus 300° F. The cryogenic and upper temperatures range of this particular model requires a careful selection of an adhesive film bonding system, that will withstand this temperature gradient. The adhesive system selected requires a curing temperature of 330° F, limiting the candidate materials that could be used to fabricate the mandrel. An article that would be subjected to normal ambient temperatures therefore would have a multitude of choices for selecting a mandrel material. On the other hand, for an article to be used in cryogenic and elevated temperature ranges, the mandrel material would be governed by the curing temperatures of the selected adhesive bonding system.

There are, therefore, numerous grades and types of materials, rigid and elastic, which are conventional and known in themselves which are suitable for fabricating the mandrel according to the present invention. A rigid material could be easily used for models of flat face configurations. For complex models, such as conical models with multiple apertures distributed along its radial profile, an elastic mandrel is preferred.

The preferred material is a room temperature curing silicone rubber (RTV-60). This is one of many grades of conventional silicone rubber, some having varying coefficients of thermal expansion and durometers. The silicone rubber is catalyzed, poured into the prepared sub-structure and allowed to cure to form the elastic mandrel. Because of the non-adhering qualities of silicone rubber, no release agent is required for subsequent removal of the mandrel from the sub-structure apertures. Pourable materials other than silicone rubber, would ordinarily require that a release agent be applied to the surface of the sub-structure that was to be poured against to form the mandrel. This presents a possibility of the release agent propagating into the bonding surface of the skin to the sub-structure and causing unbond areas in the bonded assembly. Silicone rubber is therefore preferred.

The use of silicone rubber as the mandrel material, allows the removal of the mandrel from the sub-structure and the insertion and reuse of the mandrel in the original sub-structure on a similar one.

Silicone rubber, for the above mentioned reasons, is preferred as a material for fabricating the mandrel according to the invention.

In order to realize maximum advantages of the invention, sheet member 20 will be quite thin and will preferably be not more than 0.05 inches in thickness. Still more advantages over conventional fabricating techniques are obtained when the sheet is thinner, for example, up to 0.02 inches, and maximum advantages are achieved with thickness of 0.003 to 0.015 inches. Similarly, maximum advantages are achieved where the surface against which sheet 20 is bonded is cured and where the article is provided with a plurality of apertures, for example, where the apertures constitute as

much as 10 percent of the surface area of an article.

It will be recognized that it is not necessary, to practice the invention, to eliminate the differential pressure across portions 15 of sheet member 20. In general, some differential pressure can be tolerated. However, it is preferred that the pressure be reduced by at least 75 percent and still more preferably at least 95 percent.

What is claimed is:

1. A method of fabricating an article having a cavity therein, the bottom wall of said cavity being flat and thin, comprising the steps of: providing a first member having at least one aperture extending therethrough, the wall of said aperture forming the side wall of said cavity; filling the aperture with a plug of heat-expandable solid material, one end of said plug being coplanar with the surface of said first member to which said one end is adjacent; providing a second member adjacent said surface of said first member and a layer of a heat-sensitive adhesive between said second member and said surface of said first member, said second member being thin planar sheet material having a thickness corresponding to the desired thickness of the bottom wall of said cavity; subjecting the outer surface of said second member to a high fluid pressure to induce a high differential pressure across the assembly to uniformly urge said second member against the surface of said first member; heating the assembly to a temperature sufficient to activate said adhesive to bond said second member to said surface of said first member; said heat-expandable solid material having a linear coefficient of thermal expansion at least as high as that of said first member and sufficient such that when the assembly is heated to activate said adhesive, the pressure exerted against the second planar member due to the thermal expansion of said plug of material filling said aperture substantially reduces the high differential pressure otherwise induced by said fluid pressure across the portion of the second planar member adjacent said one end of said plug; and removing said heat expandable solid material from said aperture to provide an article having a cavity with walls formed by the sides of said aperture and having a thin, flat bottom wall formed by said portion of second member adjacent said one end of said plug of elastomeric material.

2. A method according to claim 1 wherein said fluid pressure is applied while the assembly is being heated.

3. A method according to claim 1 wherein said first member is metal.

4. A method according to claim 1 wherein said second member is metal.

5. A method according to claim 1 wherein said first and second members comprise the same metal.

6. A method according to claim 1 wherein the thickness of said second member is up to 0.05 inches.

7. A method according to claim 1 wherein the thickness of said second member is up to 0.02 inches.

8. A method according to claim 1 wherein the thickness of said second member is from 0.003 to 0.015 inches.

9. A method according to claim 1 wherein the outer surface of said first member is curved.

10. A method according to claim 1 wherein said first member includes a plurality of said apertures, each of said apertures being filled with a plug of said heat expandable material.

11. A method according to claim 1 wherein said heat expandable material is more resilient than said first member and has a thermal coefficient of expansion higher than that of said first member.

12. A method according to claim 11 wherein said material comprises an elastomer.

13. A method according to claim 12 wherein said elastomer comprises silicone rubber.

14. A method according to claim 13 wherein said plug is formed in situ in said aperture.

15. A method according to claim 1 wherein the differential pressure across said portion of said second member is reduced to at most 25 percent of said high differential fluid pressure.

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